TECHNICAL REPORT

FIRE PROTECTION RISK ANALYSIS

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ABSTRACT

A fire posture study of the NASA-Lewis Research Center, Cleveland, Ohio, has been performed from a Highly Protected Risk (HPR) aspect. Factors examined in this study include the Center's:

1) fire protection water;
2) fire department;
3) fire alarm system;
4) detection and suppression systems; and
5) general hazards.

It was found that considerable emphasis is placed upon human resources for fire detection and suppression which is directly opposed to the concepts of a Highly Protected Risk. Water supplies and fire department capabilities were found to be compatible with Highly Protected Risk concepts.

General hazards were identified throughout the Center. Those which were considered deficient in fire protection and prevention systems have had specific recommendations made for upgrading existent deficiencies.

General recommendations are also presented for those deficiencies found to be distributed throughout the Center. These include uniform policies for installation of smoke detectors, automatic sprinklers and general storage facilities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I
INTRODUCTION

1.1 PURPOSE

The purpose of the study reported herein is to provide an assessment of the Fire Protection Posture of the National Aeronautics and Space Administration (NASA) Lewis Research Center from an industrial fire protection and prevention viewpoint.

Elements considered in this general evaluation are:

1) the public water supply providing the Center with domestic, industrial and fire protection water;

2) the Center Fire Department capability;

3) the Center fire alarm system;

4) detection and suppression systems within the Center; and

5) general hazards throughout the Center.

The evaluation will use as guidelines Factory Mutual (FM) standards for industrial properties that can be rated as a Highly Protected Risk (HPR); considered to be "the best protected class of industrial risk" among industrial insurers.

Basic provisions for a highly protected risk include the following conditions:

1) Set a policy and establish a plan;

2) Create and sustain management and employee interest;

3) Plan safe buildings, equipment and processes;

4) Eliminate the causes of fire, explosion, and other losses through proper education, supervision, housekeeping, and maintenance;

5) Provide automatic sprinklers and other protective equipment where needed;

6) Maintain the protective equipment in readiness; and

7) Organize and train employees for emergency action.

Perhaps the single most important factor in this list is the provision indicated in item 5. Because of the outstanding record provided by automatic sprinklers since their incorporation into the fire protection scheme, they have been recognized as the primary means of fire protection for industrial properties.

As a result of this history, the Factory Mutual System recognizes those occupancies equipped with automatic sprinkler protection (or other automatic fire detection and suppression systems compatible with the hazard) as highly protected risks and as such are considered to be standard business within the Factory Mutual System. Consequently, a preferred premium rate is provided those organizations which can qualify for this rating.

On the other hand, parts of an organization which do not qualify as highly protected risks may also be insured within the FM System, as non-standard business, and are not eligible for a preferential premium consideration. Additionally, insurance coverage of non-standard property may be refused if either Maximum Foreseeable Loss (MFL) or Loss Probability is large.

NASA's definition of a balanced risk in NASA Safety Manual NHB 1700.1 (VI) approaches the HPR concept. In terms of NASA's requirement of providing a balanced risk, we see no conflict but the Center certainly would be considered a non-standard risk since existing levels of protection do not meet FM standards for HPR. Additionally, buildings or facilities with both non-standard protection and large loss potential may not qualify for insurance coverage.

1.2 BACKGROUND

The NASA-Lewis Research Center is a facility consisting of a series of approximately 135 research structures and support facilities located on Brookpark Road at the northwest corner of Cleveland Hopkins International Airport, Cleveland, Ohio. Figure 1 is an aerial view of the Center and the adjacent Hopkins airport. The Center covers an area of approximately 350 acres and has approximately 6 miles of roadway servicing the various structures. Figure 2 is a plan of the Center providing building identification and locations.

The mission of the Center is to conduct research and provide advance technology on aircraft propulsion, space propulsion and power generation, space communication, and new terrestrial energy systems. In achieving the Center's mission therefore, a specific structure's priority is indicated in Figure 2 by the following letter designations:

A - High Priority; B - Medium Priority; C - Low Priority.

Examples of high priority structures are wind tunnels and associated support structures such as cooling towers, transformers etc. Examples of medium priority structures are large physical, chemical and engineering laboratories throughout

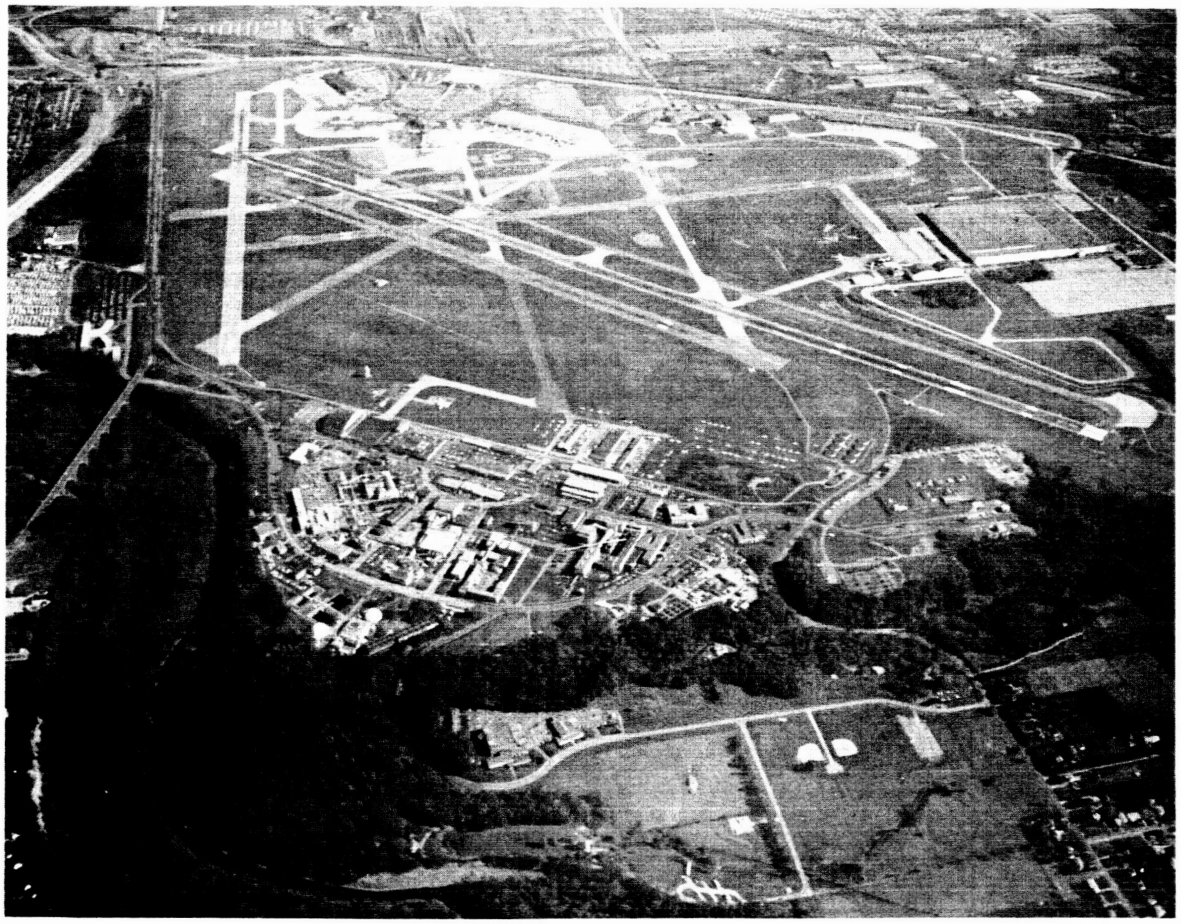
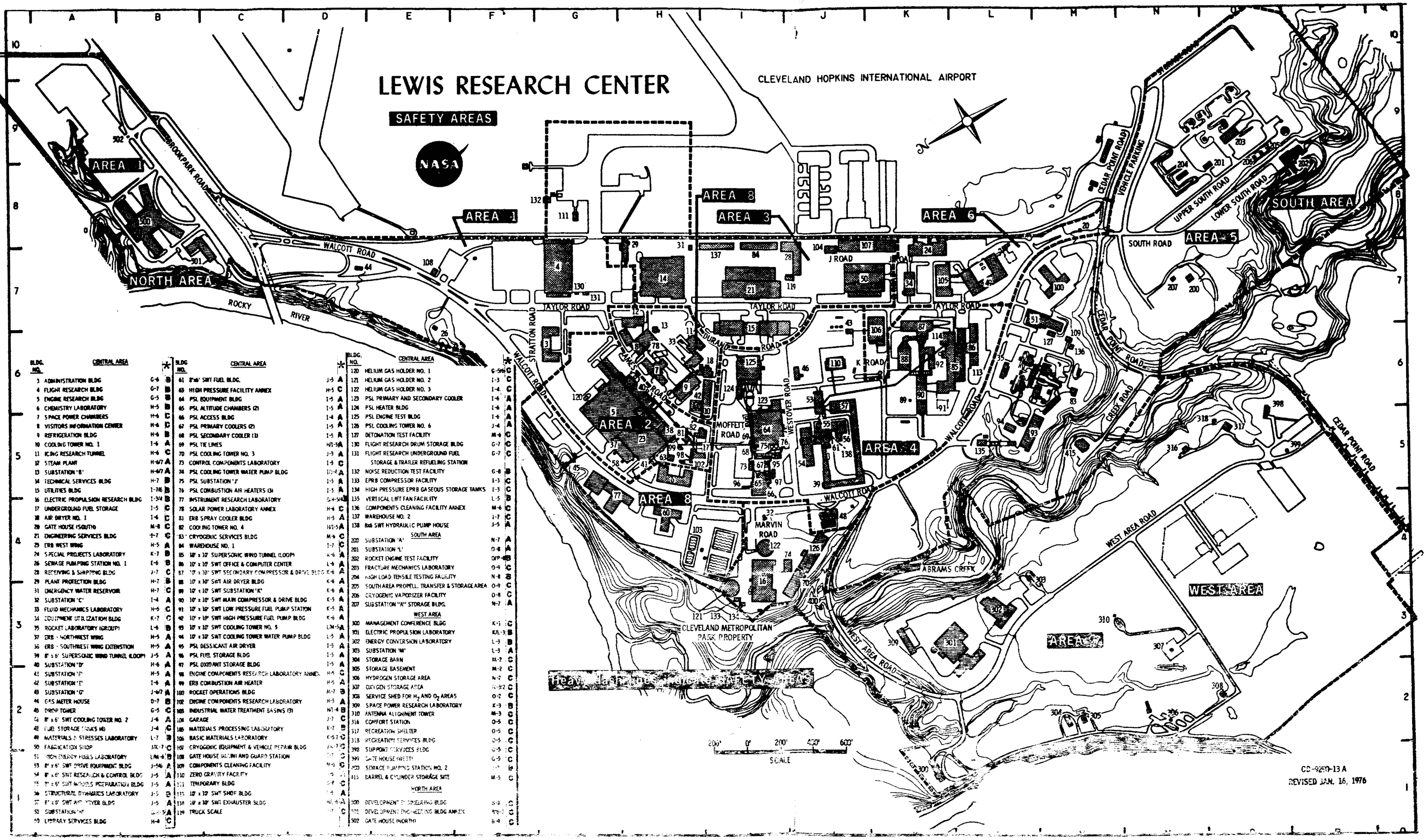


FIGURE 1 AERIAL VIEW OF NASA LEWIS RESEARCH CENTER



BLDG. NO.	CENTRAL AREA		*
3	ADMINISTRATION BLDG	G-6	B
4	FLIGHT RESEARCH BLDG	G-7	B
5	ENGINE RESEARCH BLDG	G-5	B
6	CHEMISTRY LABORATORY	H-5	B
7	SPACE POWER CHAMBERS	H-6	C
8	VISITORS INFORMATION CENTER	H-6	C
9	REFRIGERATION BLDG	H-6	B
10	COOLING TOWER NO. 1	I-6	A
11	ICING RESEARCH TUNNEL	H-6	C
12	STEAM PLANT	H-6/7	A
13	SUBSTATION 'B'	H-6/7	A
14	TECHNICAL SERVICES BLDG	H-7	B
15	UTILITIES BLDG	I-7/6	B
16	ELECTRIC PROPULSION RESEARCH BLDG	I-3/4	B
17	UNDERGROUND FUEL STORAGE	I-5	C
18	AIR DRYER NO. 1	I-6	C
20	GATE HOUSE (SOUTH)	M-8	C
21	ENGINEERING SERVICES BLDG	I-7	C
23	ERB WEST WING	H-5	A
24	SPECIAL PROJECTS LABORATORY	K-7	B
26	SEWAGE PUMPING STATION NO. 1	E-6	B
28	RECEIVING & SHIPPING BLDG	J-7	C
29	PLANT PROTECTION BLDG	H-7	B
31	EMERGENCY WATER RESERVOIR	H-7	C
32	SUBSTATION 'C'	I-4	A
33	FLUID MECHANICS LABORATORY	H-6	C
34	EQUIPMENT UTILIZATION BLDG	K-7	C
35	ROCKET LABORATORY (GROUP)	L-6	B
37	ERB - NORTHWEST WING	H-5	A
36	ERB - SOUTHWEST WING EXTENSTION	H-5	A
39	8' x 6' SUPERSONIC WIND TUNNEL (LOOP)	J-5	A
40	SUBSTATION 'D'	H-6	A
41	SUBSTATION 'F'	H-5	A
42	SUBSTATION 'E'	I-6	A
43	SUBSTATION 'G'	J-6/7	A
44	GAS METER HOUSE	D-7	B
45	DROP TOWER	G-5	C
46	8' x 6' SWT COOLING TOWER NO. 2	J-4	A
48	FUEL STORAGE TANKS (4)	J-4	C
49	MATERIALS & STRESSES LABORATORY	L-7	B
50	FABRICATION SHOP	J/K-7	C
51	HIGH ENERGY FUELS LABORATORY	L/M-6	B
53	8' x 6' SWT DRIVE EQUIPMENT BLDG	J-5/6	A
54	8' x 6' SWT RESEARCH & CONTROL BLDG	J-5	A
55	8' x 6' SWT MODELS PREPARATION BLDG	J-5	A
56	STRUCTURAL DYNAMICS LABORATORY	J-5	B
57	8' x 6' SWT AIR DRYER BLDG	J-5	A
58	SUBSTATION 'H'	G/H-5	A
59	LIBRARY SERVICES BLDG	H-4	C
61	8'x6' SWT FUEL BLDG.	J-5	A
63	HIGH PRESSURE FACILITY ANNEX	H-5	C
64	PSL EQUIPMENT BLDG	I-5	A
65	PSL ALTITUDE CHAMBERS (2)	I-5	A
66	PSL ACCESS BLDG	I-4	A
67	PSL PRIMARY COOLERS (2)	I-5	A
68	PSL SECONDARY COOLER (1)	I-5	A
69	PSL TIE LINES	H/I-5	A
70	PSL COOLING TOWER NO. 3	J-3	A
73	CONTROL COMPONENTS LABORATORY	I-5	C
74	PSL COOLING TOWER WATER PUMP BLDG	I/J-4	A
75	PSL SUBSTATION 'J'	I-5	A
76	PSL COMBUSTION AIR HEATERS (3)	I-5	A
77	INSTRUMENT RESEARCH LABORATORY	G/H-5/4	B
78	SOLAR POWER LABORATORY ANNEX	H-6	C
81	ERB SPRAY COOLER BLDG	H-5	A
82	COOLING TOWER NO. 4	H/I-5	A
83	CRYOGENIC SERVICES BLDG	M-4	C
84	WAREHOUSE NO. 1	I-7	C
85	10' x 10' SUPERSONIC WIND TUNNEL (LOOP)	K-6	A
86	10' x 10' SWT OFFICE & COMPUTER CENTER	L-6	A
87	10' x 10' SWT SECONDARY COMPRESSOR & DRIVE BLDG	K-6	A
88	10' x 10' SWT AIR DRYER BLDG	K-6	A
89	10' x 10' SWT SUBSTATION 'K'	K-6	A
90	10' x 10' SWT MAIN COMPRESSOR & DRIVE BLDG	K-5	A
91	10' x 10' SWT LOW PRESSURE FUEL PUMP STATION	K-5	A
92	10' x 10' SWT HIGH PRESSURE FUEL PUMP BLDG	K-6	A
93	10' x 10' SWT COOLING TOWER NO. 5	L/M-5	A
94	10' x 10' SWT COOLING TOWER WATER PUMP BLDG	L-5	A
95	PSL DESSICANT AIR DRYER	I-5	A
96	PSL FUEL STORAGE BLDG	I-5	A
97	PSL OXIDANT STORAGE BLDG	I-5	A
98	ENGINE COMPONENTS RESEARCH LABORATORY ANNEX	H-5	C
99	ERB COMBUSTION AIR HEATER	H-5	A
100	ROCKET OPERATIONS BLDG	M-7	B
102	ENGINE COMPONENTS RESEARCH LABORATORY	H-5	A
103	INDUSTRIAL WATER TREATMENT BASINS (3)	H/I-4	B
104	GARAGE	J-7	C
105	MATERIALS PROCESSING LABORATORY	K-7	B
106	BASIC MATERIALS LABORATORY	K-6,7	C
107	CRYOGENIC EQUIPMENT & VEHICLE REPAIR BLDG	J/K-7	C
108	GATE HOUSE (MAIN) AND GUARD STATION	[illegible]	C
109	COMPONENTS CLEANING FACILITY	M-6	C
110	ZERO GRAVITY FACILITY	[illegible]	[illegible]
111	TEMPORARY BLDG	G-8	C
113	10' x 10' SWT SHOP BLDG	I-6	A
114	10' x 10' SWT EXHAUSTER BLDG	H/I-6	A
119	TRUCK SCALE	I-7	C
120	HELIUM GAS HOLDER NO. 1	G-5/6	C
121	HELIUM GAS HOLDER NO. 2	I-3	C
122	HELIUM GAS HOLDER NO. 3	I-4	C
123	PSL PRIMARY AND SECONDARY COOLER	I-6	A
124	PSL HEATER BLDG	I-6	A
125	PSL ENGINE TEST BLDG	I-6	A
126	PSL COOLING TOWER NO. 6	J-4	A
127	DETONATION TEST FACILITY	M-6	C
130	FLIGHT RESEARCH DRUM STORAGE BLDG	G-7	C
131	FLIGHT RESEARCH UNDERGROUND FUEL STORAGE & TRAILER REFUELING STATION	G-7	C
132	NOISE REDUCTION TEST FACILITY	G-8	B
133	EPRB COMPRESSOR FACILITY	I-3	C
134	HIGH PRESSURE EPRB GASEOUS STORAGE TANKS	I-3	C
135	VERTICAL LIFT FAN FACILITY	L-5	B
136	COMPONENTS CLEANING FACILITY ANNEX	M-6	C
137	WAREHOUSE NO. 2	I-7	C
138	8x6 SWT HYDRAULIC PUMP HOUSE	J-5	A
	SOUTH AREA		
200	SUBSTATION 'A'	N-7	A
201	SUBSTATION 'L'	O-8	A
202	ROCKET ENGINE TEST FACILITY	O/P-8	B
203	FRACTURE MECHANICS LABORATORY	O-9	C
204	HIGH LOAD TENSILE TESTING FACILITY	N-8	B
205	SOUTH AREA PROPELL. TRANSFER & STORAGE AREA	O-9	C
206	CRYOGENIC VAPORIZER FACILITY	O-8	C
207	SUBSTATION "A" STORAGE BLDG.	N-7	A
	WEST AREA		
300	MANAGEMENT CONFERENCE BLDG	K-1	C
301	ELECTRIC PROPULSION LABORATORY	K/L-3	B
302	ENERGY CONVERSION LABORATORY	L-3	B
303	SUBSTATION 'M'	L-3	A
304	STORAGE BARN	M-2	C
305	STORAGE BASEMENT	M-2	C
306	HYDROGEN STORAGE AREA	N-2	C
307	OXYGEN STORAGE AREA	N-3/2	C
308	SERVICE SHED FOR H_2 AND O_2 AREAS	O-2	C
309	SPACE POWER RESEARCH LABORATORY	K-3	B
310	ANTENNA ALIGNMENT TOWER	M-3	C
316	COMFORT STATION	O-5	C
317	RECREATION SHELTER	O-5	C
318	RECREATION SERVICES BLDG	O-5	C
398	SUPPORT SERVICES BLDG	O-5	C
399	GATE HOUSE (WEST)	G-5	C
400	SEWAGE PUMPING STATION NO. 2	I-2	B
415	BARREL & CYLINDER STORAGE SITE	M-5	C
	NORTH AREA		
500	DEVELOPMENT ENGINEERING BLDG	B-8	C
501	DEVELOPMENT ENGINEERING BLDG ANNEX	B/C-7	C
502	GATE HOUSE (NORTH)	B-9	C

* Priority of Structures: A= High; B= Medium; C= Low

FIGURE 2 PLAN OF NASA-LEWIS RESEARCH CENTER the center, while low priority structures are office, storage, shipping and receiving buildings, etc.

The information needed for this study was obtained by interview of personnel responsible for specific fire protection and prevention functions, in addition to on-site inspection by the authors of this report.

II

SAFETY AND FIRE PROTECTION ORGANIZATION

Figure 3 is a management organizational chart generated by the authors from several directorate organization charts having direct impact upon the safety and fire protection objectives of NASA-Lewis Research Center. Figure 4 indicates Area and Building Safety Personnel. These charts will assist the reader who is unfamiliar with the organizational structure of the Center in understanding its management as well as provide an additional topic of evaluation for the fire protection appraiser.

It is evident from Figures 3 and 4 that upper management (the Executive Safety Board) recognizes the need for a successful life and property conservation program. This is further supported by a description of purpose, objective, responsibilities, etc. in Lewis Management Instructions LMI 8800.4A Lewis Environmental Quality Organization and LMI 1702.1B Lewis Safety Organization.

In order to make the Lewis Research Center safety problem more tractable, the reservation is broken down into eight safety areas shown roughly in Figure 2. A safety chairman and committee (see Figure 4) are assigned to each area and are responsible for assuring compliance with Center safety regulations in their area. Further, a building manager is assigned to each building within an area to monitor safety in daily operations. The Safety Office coordinates overall safety at Lewis. All operations, systems, experiments and rigs with any attendant potential hazard must obtain an operating permit from the appropriate area safety committee. This committee is able to draw on special expertise from advisory committees in the event it is required. (See Figure 4)

In addition to the preplanning effort to minimize or eliminate potential fires and explosions, Emergency Response Teams (ERT's), somewhat similar to Plant Emergency Organizations (PEO's) recommended for industrial occupancies, have been formed, whose purpose is to assist the plant protection fire fighters, when additional manpower requirements occur.

A significant difference between the two emergency groups is the active participation in fire fighting by preassigned members of the PEO prior to the arrival of fire department personnel, whereas, the ERT's function is to assist as backup after fire department arrival. These functions include supervision of control valves of the fixed fire protection systems in the affected area,

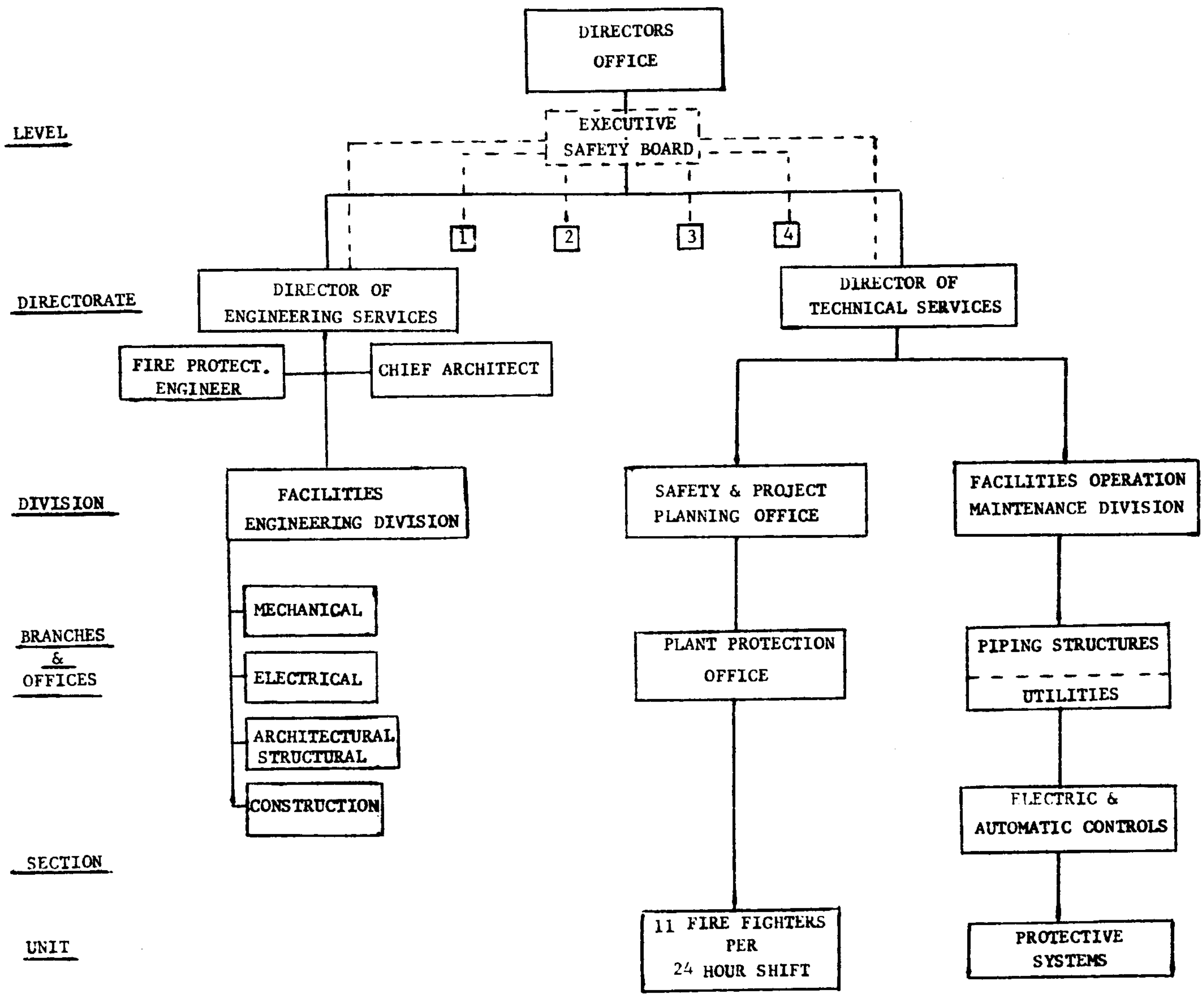


FIGURE 3 SAFETY AND FIRE PROTECTION - MANAGEMENT ORGANIZATIONAL CHART - NASA LEWIS RESEARCH CENTER

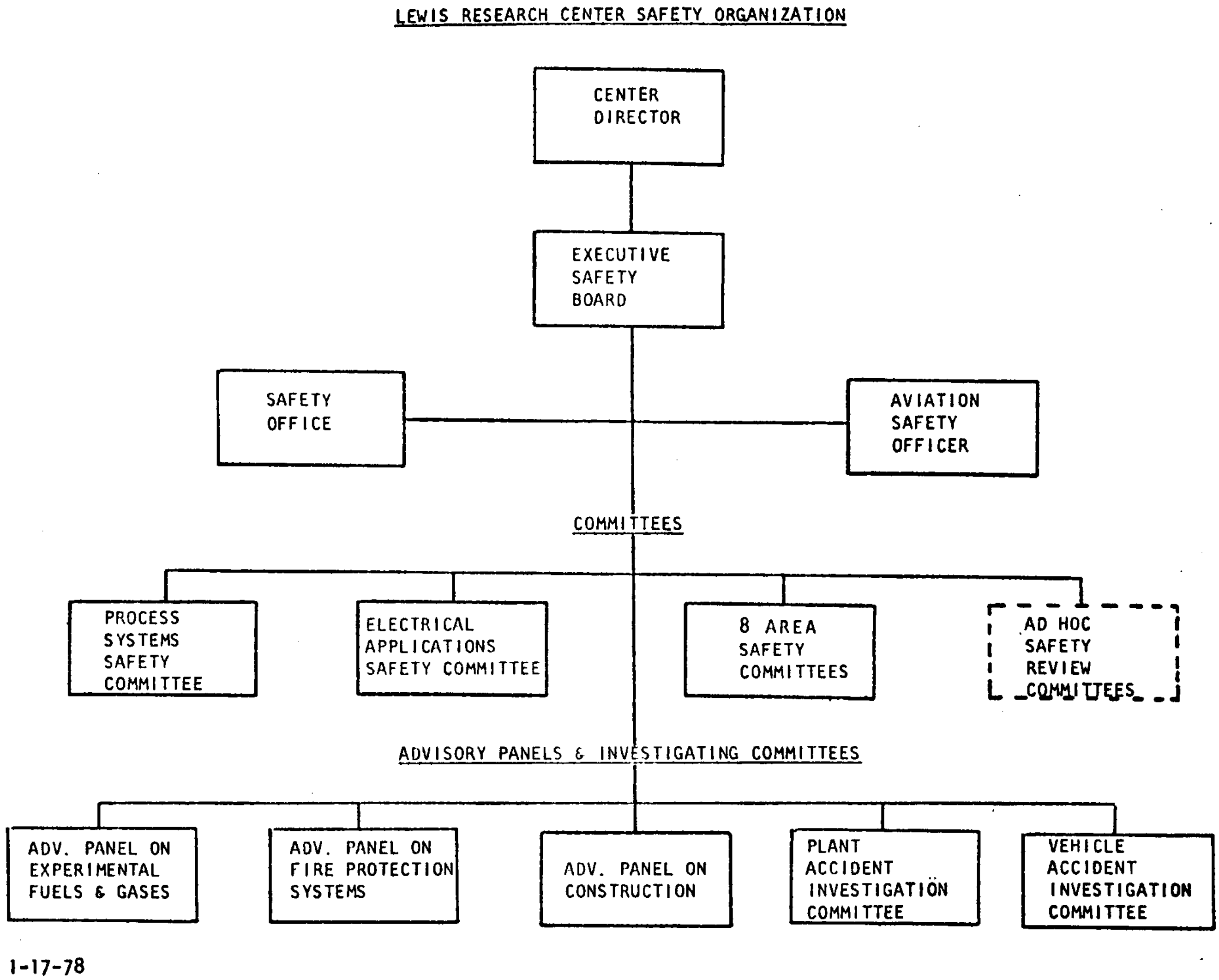


FIGURE 4 NASA-LEWIS SAFETY ORGANIZATION

utilization of first aid fire fighting (portable fire extinguishers and indoor hose stations) and functions associated with salvage operations. Since the fire department response at the Center is quicker and more reliable than that for an average industrial occupancy, the two emergency groups are considered to be equivalent. (Nevertheless, it is beneficial to incorporate the concepts of an industrial PEO into the Center's existing ERT's).

From the above examination of the management position and its structure within the Research Center, this aspect of the Fire Protection Posture is rated excellent.

III

WATER SUPPLY EVALUATION

3.1 WATER SOURCES

Water for the NASA-Lewis Research Center domestic, industrial and fire protection purposes is obtained from two supply lines from the City of Cleveland Water Department. The principal line is connected to a 30-in. diameter municipal supply main at the junction of Brookpark and Walcott Roads, and provides approximately 90 percent of the water to the facility. This line is a part of Cleveland's first High Service water supply. The water is fed through two 8-in. diameter Trident Crest Meters (No. 1772739 and 6270142) and supplies a single 24-in. diameter secondary feeder to the facility. The supply at this point is nominally 2500 gpm which can be increased to approximately 3000 gpm in an emergency. Figure 5 presents the city water network and its connection to the Center.

This connection is fed from the Crown Pumping Station located at Clague Road about four miles northwest of the Center. Crown Pumping Station is the smallest of three such facilities serving the Cleveland Water Department. All three facilities are adequately interconnected by water mains.

The Crown Filtration Plant and Pumping Station obtains raw water through an 8-ft line to a crib in Lake Erie. Raw water pumping capacity of the station is 95 million gal/day. The filtration plant has a capacity of 60 million gal/day and a clear well storage reservoir of 15 million gal. The pumping station has a pumping capacity of 75 million gal/day to the First High Service, and 24 million gal/day to the Low Service. The First High Service in Cleveland is rated as a fully-reliable public water system for purposes of reliability evaluaation of fire protection of highly protected risks.

The following principal water mains are available between the Crown Filtration plant Pumping Station and NASA-LeRC facilities:

1) Starting at the Crown facilities, approximately 8700 ft of 54-in. pipe and then approximately 11,500 ft of 42-in. pipe from south of the Crown facilites to Clague Road. From this point on Clague Road, approximately 7200 ft of 36-in. pipe runs east in Brookpark Road and reduces to a 30-in. pipe in front of the Center. This 30-in. pipe in Brookpark Road provides a major portion of water used by the Center.

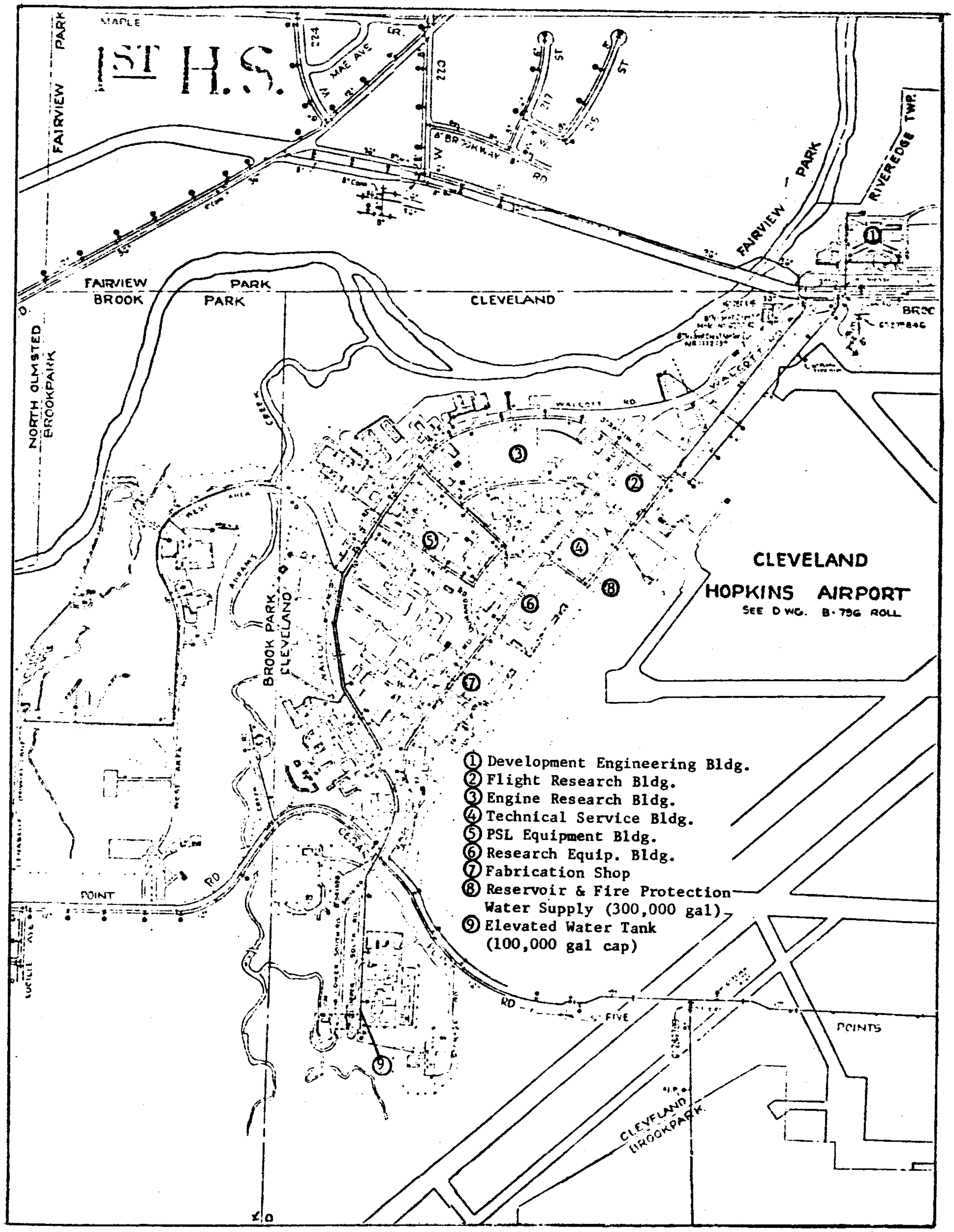


FIGURE 5 CITY WATER SUPPLY FOR NASA-LEWIS RESEARCH CENTER

2) A second smaller connection is available from the 12-in. public main on Cedar Point Road at the junction of South Road.

3) The Center is serviced by an excellent grid of underground mains and an adequate number of generally well located street hydrants. The central area of the Center has an interconnected double loop, one of which was installed in 1941. The west area of the Center has a single loop. The grid system is basically a cast-iron pipe system which appears to be in good condition. The valving, interconnecting and hydrant location are, in general, well arranged to yield a reliable water supply for manual fire fighting throughout the Center (see Figure 6).

There are plans to isolate a 300,000-gal water reservoir, installed in 1941 as the water supply for the original grid of underground mains, for the proposed foam protection for the Hangar (Building 4). This can be used for drafting in an emergency.

Also available is a 100,000-gal elevated tank located at the south end of the Upper South Road, which provides fire protection water for facilities located in the South Road's section of Area #5.

Finally, it has been indicated that in the event of an emergency, provision is made so water associated with cooling towers, (of which six, having varying capacities and indicated by * on Figure 2) can be used for fire fighting purposes.

These facilities can be helpful in providing additional water in densely populated areas, however, they should be relied upon only in an emergency situation.

Since connecting to the City of Cleveland water supply there has been only one momentary (less than a minute) unexplained interruption of water supply to this facility, which did not require any corrective action.

3.2 WATER DISTRIBUTION

The Center has very little dependence on automatic sprinkler protection. Only three structures are provided with automatic sprinklers:

1) the warehouse section of Building 21;
2) Utilities Building 15, and
3) the basement of the Computer Building, Building 86.

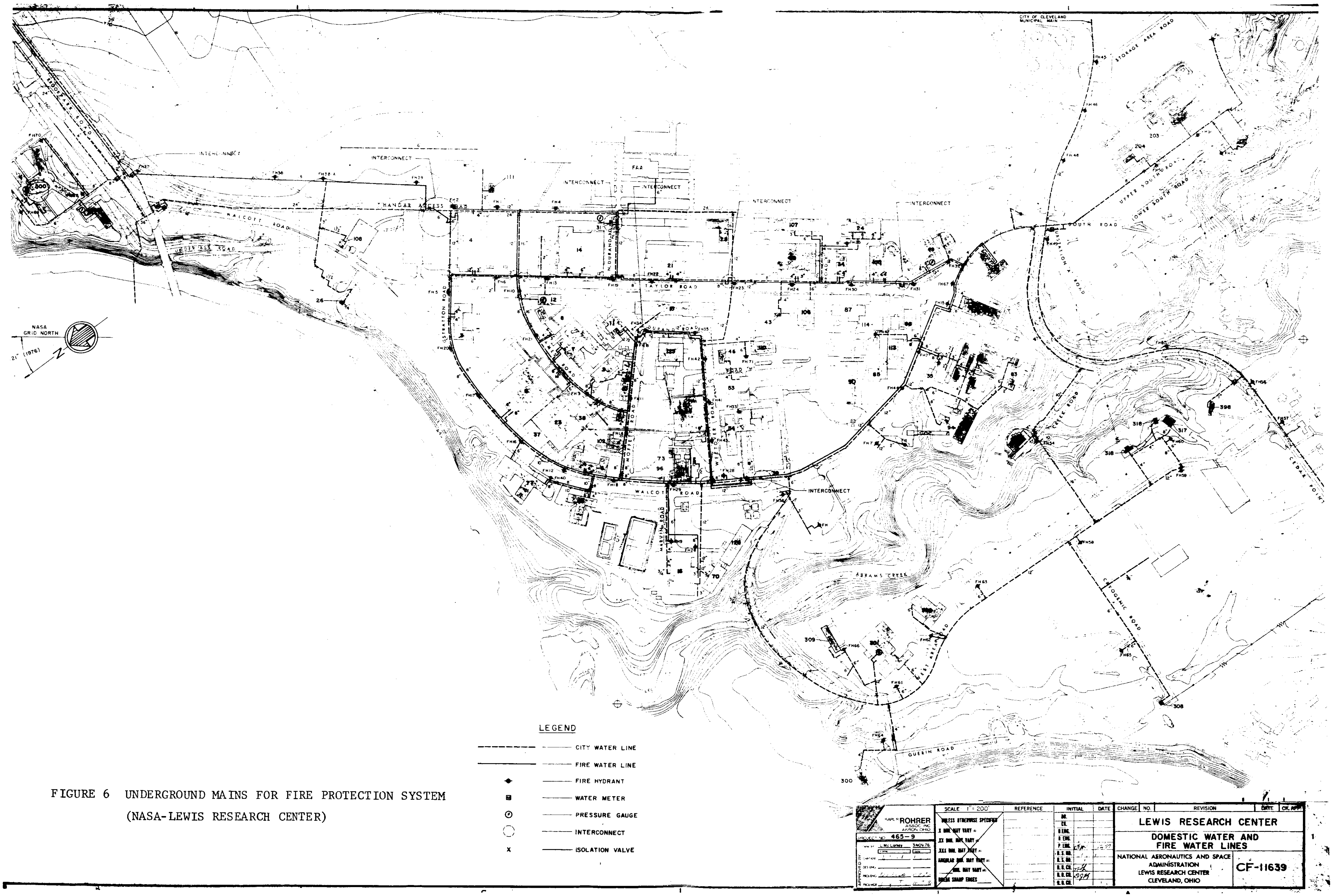


FIGURE 6 UNDERGROUND MAINS FOR FIRE PROTECTION SYSTEM
(NASA-LEWIS RESEARCH CENTER)

Otherwise, the Center depends upon water discharged from 2 1/2-in. diameter fire department hose lines fed from the hydrant grid distributed throughout the Center and 50-ft, 1 1/2-in. diameter hose lines contained in wall cabinets within the structures which are available for use by fire fighters when they arrive on the scene.

3.3 ADEQUACY OF WATER SUPPLY

From water tests conducted in 1976 by the fire department personnel of the Center, fire protection water is available at the Center at an approximate static pressure of 65 psi and approximate residual pressures of 55 psi and 50 psi for flows of 1200 gpm and 2100 gpm respectively. Test 11, conducted on Hydrants 51 and 52, indicates that the supply available at Hydrant 52 is the least in the entire Center and has a static pressure of about 69 psi and residual pressures of 40 psi and 26 psi for flows of 1040 gpm and 1380 gpm respectively. From the HPR viewpoint, the fire hazards present at the Center can be adequately protected with the available water supply by skillfully designing sprinkler systems considered necessary for those structures enumerated in Section VII.

3.4 WATER SUPPLY EVALUATION

From an industrial-insurance point of view concerning a highly protected risk, the existing water supplies for fire protection are considered to be both reliable and adequate. However, it should be pointed out that, from the same point of view, the existing fire protection (of which water supply is only a part) is considered to be poor, lacking automatic sprinkler protection at several major and important locations (see Discussion under General Hazards and Recommendations).

3.5 BASIS OF EVALUATION

This evaluation is based on the general philosophy adopted by the insurance industry for highly protected risks as opposed to that adopted by the offices of the Public Fire Marshal. The fire-water requirements specified by the Public Fire Marshal are generally several thousand gallons larger than those specified by the insurance industry for highly protected risks. The reason for this disparity lies in the needs and objectives of the two groups.

The fire-flow requirement specified by the Public Fire Marshal is that considered to be necessary to confine a fire, generally to the block of origin and to avoid conflagrations to adjacent blocks. Primary reliance of this philosophy of fire protection is upon manual fire fighting. It is the maximum, or "no deficiency," fire protection water requirement anticipated for a particular city or district over and above that necessary for maximum domestic use; it also establishes the number of engine and ladder companies, the number of fire fighters, and the number of fire stations that are necessary to produce a "no deficiency" situation.

On the other hand, the fire-flow requirement specified by the insurance industry for highly protected risks is that considered to be necessary to confine a fire generally to the immediate vicinity of the fire within a building and to avoid conflagrations to adjacent buildings. The primary reliance of this philosophy of fire protection is upon automatic sprinklers. It is the minimum fire protection water required for a good sprinkler system and for a few hose streams (250-1000 gpm) normally to be used for mop-up operations and immediate exposures.

The heavy reliance of the insurance industry on automatic sprinklers appears justified in the light of its excellent performance record. In general, 75 percent of all fires large enough to open sprinklers have been controlled by five or less sprinklers and 95 percent of such fires have been controlled by 25 or less sprinklers. Hence, the flow requirements are designed to take care of a minimum number of sprinklers (generally those over a floor area of 2000-6000 sq ft) and the minimum number of hose streams needed to confine the fire to the building of origin and to assist in mop-up operations. However, the flow requirements of the Public Fire Marshal are based on the assumption that sprinklers, if any, will fail or will only partially control a fire and that a fire which will endanger the exposures will develop. Another reason for the disparity is that application of water by hose streams is not as efficient or effective as application by automatic sprinkler systems.

3.6 SUMMARY

From the discussion in this section we conclude that the existing water supply is adequate and reliable regardless of whose criteria are used.

IV
FIRE DEPARTMENT CAPABILITY

4.1 INTRODUCTION

Due to the strong dependence upon manual fire-fighting systems, fire department capabilities are examined in terms of organization, training, facilities, equipment and preplanning.

4.2 ORGANIZATION AND RESPONSIBILITIES

The NASA-Lewis Research Center Fire Department consists of a chief, an assistant chief, two lieutenants and twenty fire fighters. The chief and assistant chief work a standard 8-hr day, while the rest of the work force is split into 24-hr on, 24-hr off shifts. The duties and responsibilities of the Plant Protection Office, in addition to firefighting activities, maintain the equipment indicated in Section 4.3, perform training exercises, inspect the hydrants annually, perform daily inspections of specifically assigned areas, perform detailed inspections of structures on an annual basis, maintain appropriate records, develop preplanned firefighting operations and assistance to the area safety managers when needed.

4.3 EQUIPMENT

The fire department has the following rolling equipment:

1. Darley Pumper - 1974 - The Darley pumper is a 1250-gpm, diesel powered, automatic transmission vehicle having a 500-gal booster tank. In addition to regular equipment, the apparatus has a 60-gal AFFF tank with a 120-gpm in-line eductor capable of supplying 2000 gal of solution in 16.7 min. At a rate of .16 gal/ft^2; the pumper will cover an area of 12,500 sq ft (an area approximately 112x112 ft).

   Available hose consists of 1) two 600-ft 3-in. supply line, 2) a 500-ft 3-in. backup line with 200 ft preconnected, and 3) a 700-ft 1 1/2-in. hose with 400 ft preconnected.

2. Crash Truck - 1968 International Chassis, Gasoline Powered - The crash truck carries 350 gal of premixed AFFF in two spheres for a total of 700 gal of solution, nitrogen-expelled at the following rates: turret, 120 gpm; handlines, 120 gpm (60 gpm each).
   At a rate of .16 gal/sq ft the truck is capable of securing 4300 sq ft (an area of approximately 66x66 ft).
3. Attack and Rescue Vehicle - 1976 Dodge, Four-Wheel Drive, 10,000 GVW, Gasoline Engine Powered - In addition to rescue equipment this vehicle carries 200 gal AFFF, nitrogen expelled, at a rate of 60 gpm. At a rate of .16 gal/sq ft the truck is capable of securing an area of 1250 sq ft (an area of approximately 35x35 ft).
4. Hale Trailer Mounted Pump received March 3, 1975 1000 gpm Single-Stage Centrifugal Pump Powered by a 218 hp Chrysler Industrial Gasoline Engine - A certificate of performance was issued February 1975, and an acceptance test was run April 12, 1975.
   The pump carries 600 ft of 3-in. and 100 ft of 1 1/2-in. hose. The Hale pump is used for water supply pumping, ERT personnel and Darley backup.
   The apparatus can respond to the most remote structure or facility within 3 min after receiving an alarm.

4.4 MUTUAL AID

The Center has executed mutual aid contracts with the following adjacent fire departments:

1) Cleveland Hopkins International Airport;
2) the City of Cleveland;
3) the City of Brookpark; and
4) the township of Riveredge.

Each contract identifies the apparatus to be provided and the procedures to be followed by all interacting agencies when responding to a request for assistance.

4.5 TRAINING

Department personnel appear to be well trained in all aspects of fire fighting and especially in some specific hazards associated with the Center. Open pit fire training programs are conducted for fire fighting personnel at least once a year and more frequently depending upon circumstances, such as time, availability of equipment, etc.

4.6 PREPLANNING

The department's preparation of individual building prefire plans of attack is an excellent device to assure uniform understanding of tactics as well as providing officers on mutual aid assignments with a rapid assessment of the fire ground. This device can also be used as a visual training aid for new personnel.

4.7 LOSS STATISTICS

The loss statistics presented in Table I summarize the losses experienced by the Center during the last 10 years. The record is excellent in terms of conservation of life and property from fire and explosion. Significant in this record is the noticeable reduction in the number of fire and explosion incidents over the 10-yr period. This record is further enhanced when the two large losses are considered. The incident involving the F-8 aircraft was certainly beyond any control which could be preplanned by the fire department, while the PSLEB explosion was not a combustion associated phenomena. Thus, the overall record is highly favorable.

4.8 EVALUATION

The fire department, rated from the viewpoint of a Plant Fire Protection Department is satisfactory. In conjunction with mutual aid, it can probably handle most fire incidents at the Research Center with the possible exception of Cooling Towers 3 and 6. Further discussion on these hazards is presented in Sections VII, General Hazards and IX, Recommendations.

TABLE I

TEN YEAR LOSS EXPERIENCE

Fiscal Year	Exp.	Fire	Explosion Cost	Fire Cost	Inj.	Total Cost	Remarks
1966	1	37	50	1,513	0	1,563	
1967	8	42	1,525	8,135	0	9,760	
1968	2	30	325	2,893	2	3,218	Two men burned cleaning VAT fire
1969	2	27	100	2,380	0	2,480	
1970	0	2	0	930,628	2	930,628	F-8 plane crash landing 10'x10' drive fire
1971	1	8	294,000	3,184	1	297,184	PSLEB explosion
1972	0	9	0	2,400	0	2,400	
1973	1	6	18,000	772	0	18,772	HLTTF explosion
1974	0	8	0	1,815	0	1,815	
1975	0	2	0	60	0	60	
Incl. to 12/31/76	0	7	0	0		0	Return to calendar year to offset 6 month period

1968 • Two Lewis employees suffered third degree burns when a tank of cleaning alcohol ignited. One of the men used an extension cord with a hot light bulb for lighting the working area. The heat of the light caused the alcohol fumes to ignite. No facility down time.

1970 • While attempting to land at the Cleveland Hopkins Airport, A Lewis pilot flying a F-8 plane, crashed. The pilot and a Plant Protection rescuer were injured. The plane was damaged beyond repair.

• 10'x10' Drive Fire. Extensive damage. No facility shut down.

1971 • Explosion at the Propulsion Systems Laboratory. The industrial mishap was not the result of combustion or detonation. Caused by a pressure buildup in the exhaust duct downstream of an exhauster discharge valve. Immediate cause of which resulted in a rupture in the system. One Lewis employee was injured. He suffered a compound fracture of the right elbow when struck by flying debris. Approximately two weeks lost until building facilities put back into service. Other services continued as building was repaired.

1973 • High Load Tensile Testing Facility. Hydrogen detonation caused explosion. Extensive damage resulted. Facility was temporarily repaired and research continued. There were no injuries.

From the viewpoint of an industrial risk, it is our opinion that some of the department's activities should be oriented to more frequent inspections of:

1) existing sprinkler systems, currently the responsibility of the Protective Systems Group (see Figure 3); also, see comments under Suppression Systems;

2) the CO_2 systems; and

3) building inspections.

Considerable dependence appears to be given to AFFF foams as a fire suppressing agent. There appears to be adequate capability with this agent from the three Lewis vehicles, and with agent which would be carried by vehicles responding in a mutual aid situation. Thus, should the crash truck (a nine-year-old, rehabilitated vehicle) be considered for replacement, a second pumper (the Darley or equivalent) would be a reasonable replacement since 1) no loss of AFFF capability would be experienced, 2) a more efficient AFFF system would be provided, and 3) an expanded water pumping capability would be available in providing earlier two-point attacks in the event of a fire, rather than waiting for mutual aid assistance.

V

ALARM SIGNALS

The Center's alarm system is a proprietary system as defined by NFPA Standard 71A, since fire and supervisory alarms are received at a point located on the property where equipment is continuously monitored by a competent attendant.

5.1 SIGNALS TRANSMITTED

The following general signals are transmitted over hard lines from the point of origin to the supervisor's desk at the fire station:

1) Fire signals from manually operated boxes and fire detectors; and
2) Supervisory signals from boilers and other systems under continuous supervision.

In addition to transmitting a signal to the Fire Station, local audible and visual alarms are presented for evacuation of personnel or action by personnel located at the point of origin, for example, a flame failure device on a boiler.

5.2 TRANSMISSION SYSTEMS

Two signal transmission systems are in use. The first consists of three d.c. underground loops while the second alarm system consists of the PAX telephone system and, an interface from this system to an underground d.c. cable running to the fire station. The interface is located in the PAX exchange in Building 15. This system serves outlying areas not within the range of the three underground loops, since PAX lines service all structures within the Center.

In addition to transmitting supervisory and alarm signals, local audible and visual alarms are presented at the origin of the signal for personnel evacuation purposes, as well as remedial action in the event a supervisory alarm is given.

Finally, an emergency telephone number (17) is provided for verbal communication of an alarm.

5.3 EVALUATION

The underground alarm system is satisfactory and the use of PAX lines is an economical approach to extend alarm coverage when necessary. However, the location of the PAX fire alarm interface in the telephone exchange is highly vulnerable due to the combustibles in the exchange equipment and the materials of construction used for the exchange office (also see the discussion in Section VII Computers, Control Rooms and Telephone Exchanges).

It is understood that this part of the building is scheduled for early rehabilitation and that the exchange office will be generally constructed from fire resistive materials. However, considerable combustible materials in the form of cables and fine wire are widely distributed throughout the exchange. In view of the importance of this facility to the fire protection plan, the fact that it is generally unattended, and that considerable and widely distributed combustibles are present, it is recommended that automatic sprinkler protection be provided for this occupancy.

Thus, the primary underground system can be rated good while the PAX system is poor at the present time. This rating is based upon the potential of telephone failures due to the mechanical failure of the switchgear employed in the PAX system, the unsupervised nature of the system in addition to the reasons previously cited. It is further felt that an easier emergency number such as 111 may be more readily remembered than the number 17.

VI
DETECTION AND SUPPRESSION SYSTEMS

6.1 DETECTION SYSTEMS

The primary mode of fire detection at the Lewis Research Center is the ionization-type smoke detector. Other types of detectors include: oxygen detectors, principally for personnel protection in the event of large discharges of nitrogen in laboratory areas; a supervisory system for flame failure devices associated with boilers; fusible links in those buildings having sprinkler systems; and combustible gas detectors. The left hand and central columns of Figure 7 delineate these systems.

6.1.1 Distribution and Location

A total of 19 out of 116 buildings have various degrees of fire detection using these types of detectors (see Table II). A total of 344 smoke detectors are installed with distribution according to mission priority as defined in Section I.

Ionization detectors are provided in some areas of high dollar and mission value, for example, the computer center (Building 86), the Noise Reduction Test Facility Control Room in the hangar, Building 4, and Buildings 301 and 302. These alarms provide a local alarm for personnel evacuation, as well as presenting an alarm at fire headquarters for response of firefighting apparatus and personnel.

Fire detection and suppression are provided in the form of automatic sprinklers in the basement of Building 86, the warehouse section of Building 21, and sections of Building 15.

Several additional detection systems are provided in a random manner, for example, the ADT system in Building 15 outside of the PAX telephone exchange, which has obviously gone through several changes of occupancy.

Fifteen ultraviolet (uv) flame detectors are installed on research apparatus for flame failure and fire detection purposes. All such installations are associated with either a Class A or Class B structure except for two installations in a Class C structure.

TABLE II

BUILDINGS PROVIDED WITH SMOKE DETECTORS

Class of Structure	No. of Detectors	No. of Buildings With Detection	No. of Buildings* In Class	Percent Provided With Detection (smoke)
High	203	7	37	19
Medium	60	5	24	21
Low	70	7	55	13

*These statistics do not include electrical substations, water cooling towers or open storage areas.

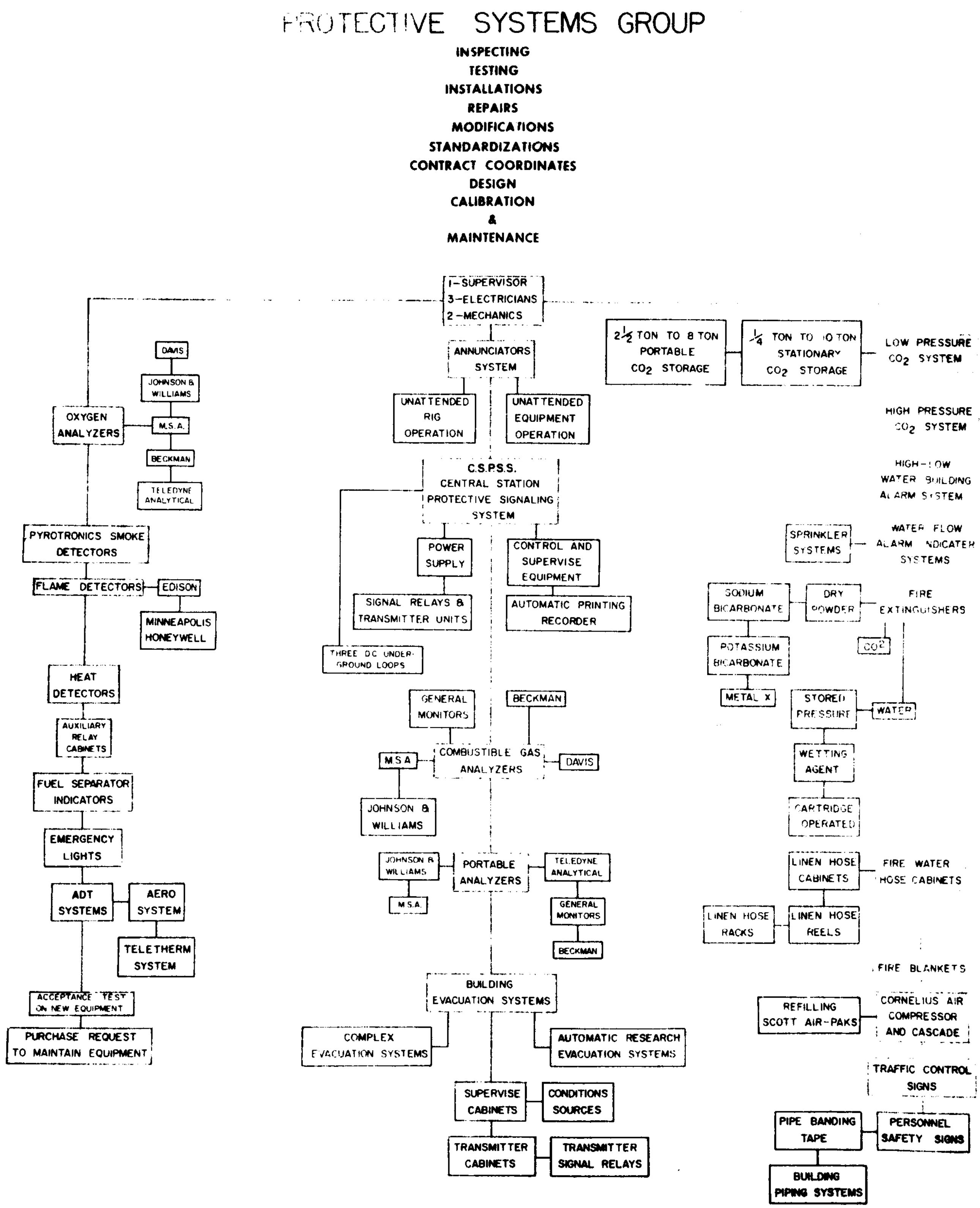


FIGURE 7 PROTECTIVE SYSTEMS GROUP

Flame failure devices in the form of solid state detectors are provided on all the boilers throughout the Center. These devices for unattended boilers are supervised from the dispatcher's desk at the fire station.

In addition to these automatic devices, numerous manually operated alarms are distributed throughout the Center and foot patrols are made every half hour after normal working hours in selected buildings.

6.1.2 Discussion

An apparent inconsistency in policy concerning types and location of smoke detectors exists for the following reasons:

1) Ionization smoke detectors have been provided in the Computer Building No. 86, the Noise Reduction Test Facility Control Room located in the hangar, (Building 4) and Buildings 301 and 302. These have high dollar and mission value. Equally high dollar and/or mission value control rooms throughout Building 5 are without any form of fire detection on the basis that no combustibles are present. However, considerable amounts of combustibles, present in the form of plastic pneumatic tubing, cabling and circuit boards in the instrumentation pose a potential fire hazard.

2) Building 301, Electric Propulsion Laboratory, has 23 ionization detectors located in the high-roofed area, yet none are provided in the laser laboratory and associated control room or in the area housing the diffusion pumps. It is our opinion that this structure is only partially provided with smoke detection devices.

3) Engineering Office Building 500 contains a large cafeteria, an auditorium seating 470, a moderate-sized boiler room and a small cooling tower, in addition to numerous offices. Except for flame failure guards provided on the boilers, no automatic fire detectors are provided in this structure.

In view of the Center's commitment to life safety, it would be a reasonable suggestion that smoke detectors be provided in those areas where large groups of people can congregate, especially in locations where uncontrolled smoking is allowed as in the auditorium.

In contrast to the lack of smoke detectors in Building 500, the visitors' information center (Building 8), a building where large groups of people can congregate, has 21 smoke detectors provided for sensing an incipient fire, which reflects the Center's commitment to life safety.

Twenty-four, out of a total of approximately 116 structures have various degrees of automatic fire detection devices installed. Table II shows that emphasis has been placed on providing smoke detectors at least in those structures having high mission priority (which may also be directly correlated to high dollar value).

However, this brief analysis indicates:

1) the dependence placed upon human sources for fire detection;

2) some active mode of fire detection has been provided for High and Medium priority structures, with Low priority types only slightly less than the higher priority structures; and

3) some inconsistencies in providing protection uniformly to structures within the same class.

More structures should be provided with at least automatic detection systems. These are delineated in Section IX under Recommendations.

6.2 SUPPRESSION SYSTEMS

The primary fire suppressant is water delivered, generally, from manually controlled 1 1/2-in. hose lines contained in wall cabinets located at entrances to buildings, stairwells and other convenient locations. Hand-held dry chemical CO_2 or pressurized water extinguishers are also available at these locations.

Automatic sprinkler systems are provided in the warehouse section of Building 21, the basement of Building 86 and Building 15.

Complementing these systems are 18 low-pressure carbon dioxide (CO_2) supply systems. The CO_2 is delivered to the fire location, either through nozzles or from hand-held hose lines. In some cases completely automatic, total flooding systems are provided, utilizing Heat Actuated Devices (HAD's).

6.2.1 Distribution and Location

The suppression systems are distributed according to building classification as indicated in Table III.

In this distribution, the more highly ranked mission-oriented structures have been provided with automatic suppression systems. Again, from a total of approximately 116 structures only about 18 percent are provided with automatic protection. The percentage of High Priority buildings provided with either complete or partial protection is about 27 percent.

TABLE III

BUILDINGS PROVIDED WITH SUPPRESSION SYSTEMS

Building Priority	No. of CO_2 Units	No. of AS*	Total
High	8	2	10
Medium	7		7
Low	3	1	4
	18	3	21

*AS - Automatic Sprinkler Systems

6.2.2 Evaluation

The Center relies very little on automatic suppression systems. As with detection systems, considerable dependence is placed upon manual response. In general, it is our opinion that more reliance should be placed on automatic suppression systems, especially automatic sprinkler systems for Class A structures.

Specific areas wherein added detection and suppression systems are recommended will be discussed in Section VII General Hazards.

As a result of the small percentage of automatic detection and suppression systems currently in use by the Center, we rate these aspects poor, especially since some buildings including Class A structures without automatic detection could have an incipient fire underway for at least a half hour before being detected by a watchman while additional delay could be expected for transmitting the alarm to the fire station and response of fire fighting personnel and equipment.

VII

GENERAL HAZARDS

General hazards identified within the NASA-Lewis Research Center, as well as their potential hazard, are identified in the following discussion. Specific recommendations for protection are presented if needed.

7.1 AIRCRAFT OVER FLIGHTS

When Runway 7 at Cleveland's Hopkins International Airport is used for takeoffs to the northwest, low-flying aircraft pass directly over the Research Center. The possibility of a catastrophic incident occurring if an aircraft loses power, for example, on takeoff is present, although it is of low probability. Should such an incident occur and approach the catastrophic degree, it would be expected that the Center's Emergency Program complying with NASA Policy Directive 1040.3 would be implemented.

7.2 POWER DISTRIBUTING SUBSTATIONS

A total of 12 power-distributing substations are located throughout the Research Center capable of handling a wide range of power distribution. Air, oil and askarel insulated transformers are used, depending upon the power handling capacity of the substation and the year of installation. In general, the transformers are installed in compliance with FM and NFPA standards and are equipped with temperature and overflow alarms.

The highest hazard present in the substation category is associated with those transformers using mineral and other combustible oils for insulation.

Fires in oil-insulated transformers result principally from breakdown of insulation caused by overload, switching or lightning surges, gradual deterioration, low oil level, moisture or acid in the oil, or failure of an insulating bushing. Arcing that follows an electrical breakdown can burn through the case or vaporize the oil, creating pressure sufficient to force off the cover or rupture the casing. To prevent fire damage from spreading beyond the involved unit, one of the following protection measures should be provided for transformers of all sizes between 10,000 and 99,999 kva:

1) A 25-ft minimum clear space between units and 2 1/2-in. hose with two portable spray nozzles, or

2) Noncombustible barriers between units and 2 1/2-in. hose with two portable spray nozzles, or

3) Fixed automatic water spray.

In addition, coordination studies should be provided periodically to all substation electrical protection elements to assure that proper ratings and time sequences are being maintained.

Adequate automatic supervision of all transformers is maintained at the power control center since personnel at the control center can conveniently switch power from one substation to another depending upon demands.

The power distribution center is located at the northeast corner of Building 21 and due to its importance to the Center's mission and the dollar value of the equipment involved, should be provided with automatic sprinkler protection.

7.3 COOLING TOWERS

A total of six cooling towers of various sizes having wooden or plastic exterior casings are located throughout the Research Center (see Figure 2). Potential hazards involving these towers are based on 1) the close proximity of trees to cooling towers #3 (Building 20), #6 (Building 126), and #5 (Building 93), and 2) the proximity of four fuel storage tanks (Facility #48) to tower #6.

Should a fire of significant size occur in either of towers #3 or #6, it is felt that the tower in which the fire occurred would be lost, while the second tower could also be lost due to the very small separation between these two towers. A fire of high magnitude in either tower would be beyond the existing combined capabilities of the Research Center Fire Department and the mutual aid support provided by the agencies cited previously.

The following specific recommendations are provided for cooling towers:

1) Automatic sprinkler protection should be provided throughout the cooling towers in accordance with NFPA Standard No. 214;

2) The fan motors should be interlocked with the sprinkler system so that the cooling tower fan motors will be stopped upon actuation of the sprinkler system. Where the continued operation of the fans is vital to the process, a manual override switch may be provided to reactivate the fan when it is determined that there is no fire;

3) Because of the serious fire exposure presented by the aboveground flammable liquid storage tanks to cooling tower #6, the combustible-exposed surfaces of the tower should be protected by an automatic water spray system.

7.5 HEATING PLANTS

Building 12 houses five boilers and is the main supply of steam to the Research Facility. Individual boilers are located in other buildings (for example, Buildings 500, 301).

All boilers are equipped with appropriate flame failure devices. The unattended ones are supervised at the fire station. In the event of a failure associated with an event in the ignition sequence, a local audible-visual alarm is given in addition to being transmitted to fire headquarters. If the boiler is unattended (after normal working hours), a member of the roving fire patrol is sent to the boiler in question to assess the situation, take remedial action if possible, and notify appropriate personnel if the situation is beyond the capability of the fire fighter.

Perhaps the most significant method of avoiding fires and explosions in such equipment is to test and inspect safety controls periodically to insure proper functioning in an emergency. A policy does exist at the Center.

The following inspection schedule is intended to serve as a further guide for developing a report form suitable to the specific boilers. Details and time intervals could vary according to the plant operation and equipment involved. The report forms and schedules may also include inspections of boiler room fire hazards.

BOILER INSPECTION SCHEDULE

DAILY

1. Flame failure detection system.

WEEKLY

2. Igniter and burner operation.

MONTHLY

1. Fan and airflow interlocks.
2. Fuel safety shutoff valve(s) for leakage.
3. Low fire start interlock.
4. High steam pressure interlock.
5. For Oil: Fuel pressure and temperature interlocks.
6. For Gas: (a) Gas cleaner and drip leg.
   (b) High and low fuel pressure interlocks.

SEMIANNUALLY OR ANNUALLY, as required

1. Igniter and burner components.
2. Combustion air supply system.
3. Flame failure system components.
4. Piping, wiring, and connections of all interlocks and shutoff valves.
5. Combustion control system.
6. Calibration of indication and recording instruments.

As required for oil-firing

1. Atomizers.
2. Strainers.

7.5 FUEL STORAGE FACILITIES

Storage facilities are provided for liquid hydrogen and oxygen (Facility 306 and 307), and other fuel (Facility 48). The liquid hydrogen and oxygen storage areas are in a remote location and are relatively free from any ignition sources.

In the event that one of the cryogenic storage facilities should be involved in a fire, it is expected that the fire department would wet down the surroundings and the container if possible and allow the fuel to be consumed, thereby avoiding the formation of a vapor cloud which could potentially be ignited.

The fuel storage tank facility is properly diked and it would be expected that a fire involving this storage would require special fire fighting measures, especially because of the proximity of the tanks to the water cooling towers. Since most of the heat from such a fire will be transferred by radiation, the wooden exterior of the cooling towers could be seriously compromised in the event of a fire involving the storage tanks. It is conceivable that piping could be arranged on the exposed end of the water cooling tower such that a water curtain could be formed to provide protection from such an exposure; water being cooled in the tower could be diverted for this purpose.

Other fuel storage areas are underground (Building 12 - 61,500 gal Bunker #2 fuel) and jet fuel at Buildings 4 and 17; these are properly installed.

Temporary fuel supply facilities are provided at Buildings 301 and 500, and are installed with temporary dikes to avoid a widespread spill. We do recommend that such temporary storages be located at least 35 ft from the structure being serviced.

7.6 FLAMMABLE LIQUIDS AND GASES

A flammable material storage area (Building 415) is sufficiently remote from other structures and, therefore, does not form a hazard to them. Flammable gases are suitably stored in isolated racks at Buildings 16 and 301. Incoming hazardous materials at the Receiving Area, although not held for long periods of time, should be isolated from other materials, e.g., by a physical, fire resistive barrier, and, in the case of flammable liquids, they should be placed in a tray to prevent their spread in the event of a broken container.

7.7 COMPUTERS, DATA ACQUISITION SYSTEMS AND TELEPHONE CENTRAL OFFICES

Large electronic computers, data acquisition consoles, and telephone exchange offices are considered important since 1) they are highly expensive items; 2) they contribute significantly to mission objectives; and 3) their replacement in the event of a loss would generally require long lead times.

7.7.1 Computer Rooms

Electronic computer systems represent a large and concentrated value susceptible to severe damage from heat or smoke. The interruption of data-processing operations, research and scientific projects and other operations that involve computer systems can be severe. Such systems are located in Buildings 5 and 86. Depending on the value of the equipment in the control room and the importance of each project, control rooms associated with tests may have to be treated as computer rooms. The following safeguards are recommended to minimize the loss and research interruption due to a fire in computer rooms:

1) Provide individual cutoff rooms for computer units, record storages and necessary operating supplies. Access doors should be self-closing;

2) Provide drainage in the main floor beneath the raised floor of the computer room;

3) Install complete automatic sprinkler protection;

   a) throughout the computer room. However, sprinklers may be omitted in computer rooms of noncombustible construction where there is no use of cards, paper, and other combustibles in the room, and all processing is done by either tapes or discs with no storage of tapes or discs within the room;

   b) in all record storage areas, other storage areas and maintenance areas where the amounts of combustibles would warrant such sprinkler protection;

   c) in noncombustible spaces containing cables, unless the cables are covered by or enclosed in, a noncombustible material, or are few or well separated, or unless automatic CO_2 or Halon 1301 protection is provided. A 'few' cables are considered to be no more than about 15 cables in a group, with groups separated by several feet so that a self-spreading fire in the cables is unlikely;

d) in the space beneath combustible raised floors, unless automatic CO_2 protection is provided. CO_2 protection for this application should be of the total flooding type with extended discharge to maintain an extinguishing concentration for at least 30 min in the space;

4) When sprinkler protection is needed, provide wet-pipe systems with ordinary-temperature rated heads. However, a supervised preaction system, a dry system, or an ON-OFF multicycle sprinkler system is acceptable;

5) In addition, for high valued or important installations, provide an approved automatic, smoke-actuated fire alarm system in the computer room, under any raised floors, in the air-conditioning system return air duct, and in rooms or areas containing numerous wires and cables for process and operations control. The location of detectors should be based on air flow and other physical arrangements;

6) Limit records, paper supplies, spare tapes and disk packs or other combustibles in the computer room to the working minimum needed for current or daily requirements. Store such records in normally closed metal cabinets. For those operations involving considerable paper and other combustibles, the combustibles in the computer room should be limited to much less than a day's needs;

7) Provide normally closed metal cabinets or containers for the main storage areas of original and all duplicate records in their respective locations.

7.7.2 Telephone Central Office

Telephone central office equipment also represents a large and concentrated value susceptible to considerable damage due to fire, heat and smoke. To minimize fire losses, the following safeguards are recommended:

1) Provide automatic sprinkler protection with water flow alarms in telephone central offices. This protection should be provided in the distribution frame and switching equipment areas. Arrange the sprinkler waterflow alarms to transmit to a constantly attended location, such as the fire station;

2) Provide an ample and readily available supply of waterproof covers to protect telephone equipment from water damage.

In general, wherever protection is provided, manually operated hose lines discharging CO_2 for local application from low pressure systems provide the primary means of protection against the occurrence of fires in such occupancies. In addition 1 1/2-in. water hose lines are available, as well as hand-held portable dry chemical extinguishers. The specific recommendations indicated are those which one would expect to find in a highly protected risk.

7.8 COMBUSTIBLE CONSTRUCTION

Automatic sprinkler protection is recommended whenever combustible roof construction is involved. Roof construction is considered to be combustible if it involves:

1) wood deck, or

2) metal deck with insulation or adhesive or vapor barrier that is not approved by FM or other for use in Class I metal deck.

Table IV provides a preliminary list of buildings in which automatic sprinkler protection is recommended to comply with the HPR concept.

7.9 COMBUSTIBLE OCCUPANCIES

Automatic sprinkler protection is recommended whenever the occupancy is combustible. Small areas of storage scattered throughout various buildings (including civil defense storages) should be protected by automatic sprinklers. Examples of such areas are: C and T Basement, Building 5, Basement of Building 500, First Floor of Buildings 301 and 302. Other areas that need sprinkler protection because of combustible occupancies are:

Building No.	Building	Area Needing Sprinklers
137	Warehouse #2	Entire
5	ERB	Print Room, Photo Room
60	Library Services	Basement and Portions of First Floor

TABLE IV

BUILDINGS REQUIRING AUTOMATIC SPRINKLER PROTECTION

Building No.	Building	Roof Construction	Area (sq ft)
8	Visitor Center	Wood	16,860
9	Refrigeration	"	12,447
15	Utilities	Steel & Wood	
28	Receiving and Shipping	Insulated-Metal Deck	13,164
84	Storage	"	8,840
105	Material Processing Lab	"	16,419
107	Cryogenics Equipment and Vehicle Repair	"	23,986
125	P.S.L. Engine Test Building	"	25,000
203	Failure Mechanics Lab	"	5,605
415	Rocket Combustion Lab	"	4,078
16	E.P.R. Building	"	20,000
54	Office and Control Room	"	15,100
57	8 x 6 Air Dryer	"	5,500
110	Zero G	"	5,000
309	S.P.R.L.	"	6,000

VIII

CONCLUSIONS

The following conclusions are reached as a result of the Fire Posture Risk Analysis conducted for NASA-Lewis Research Center.

1. Management on all levels participates to a high degree in the life and property conservation programs. Conservation of life is the prime objective.
2. The facility is provided with an ample and reliable supply of water from the City of Cleveland for its domestic, industrial, and fire protection requirements.
3. Fire Department capabilities and equipment are adequate to cope with most incidents. Incidents involving fires in water cooling towers can be expected to be highly challenging to the fire department even with the assistance provided by mutual aid. Other major incidents, such as aircraft ground incidents, can be adequately handled by the fire department.
4. The alarm systems, especially the three underground loops and associated equipment, are suited to the Center's requirements, although only providing partial coverage of the Center at the present time.
5. The PAX alarm system is considered to be a less desirable system than the underground loops due to its vulnerable location in Building 15, lack of any fire protection inside the exchange and close proximity to the highly flammable wood, paint and model shops which, with the exception of the paint booths, do not have any automatic detection and suppression systems.
6. A uniform policy for placing detectors in buildings is not apparent since several inconsistencies exist for installation of fire detectors in equivalent occupancies.
7. A high reliance is placed upon manual detection and suppression systems, which in some cases could cause a delay in detection up to 30 min due to the absence of automatic detection and scheduled watchman's rounds. Thus, it may be possible for a fire to gain considerable headway in some locations before detection and suppression occurs.

8. General hazards, such as boilers and transformer banks, are well protected, although no apparent inspection schedule is provided for these facilities.
9. High dollar and mission value structures, especially computer rooms, telephone exchanges, and control rooms are not generally provided with automatic fire detection and suppression system.
10. General storage policy appears to be casual without any specific policy concerning provision of fire protection in areas used for storage (for examples, Buildings 5, 500, 302 and 301).
11. Specific deficiencies observed in a number of buildings will be examined in more detail under Phase II of this program.
12. From an HPR viewpoint the Center would be rated unsatisfactory due to the minimal utilization of automatic suppression systems. On the basis of evacuating personnel the Center would be rated satisfactory.

IX

RECOMMENDATIONS

The following general recommendations are reduced to two separate categories relating to 1) the human element, and 2) policy. Recommendations associated with specific hazards will be found in Section VI.

9.1 HUMAN ELEMENT RECOMMENDATIONS

1. Establish a weekly fire prevention inspection.

   To insure that all fire protection equipment is in working order and to prevent the start and spread of a fire, weekly recorded fire prevention inspections of all items affecting the fire safety of the plant should be made. This inspection should note deficiencies in electrical wiring, housekeeping, flammable liquid safety, and any other item which may lead to a fire. In addition, all valves controlling sprinkler water or carbon dioxide to fixed protection systems should be physically tested for the open position.

2. Lock open fire protection system control valves.

   To prevent unauthorized closure, either during or before a fire, all valves controlling water supplies to automatic sprinkler systems and carbon dioxide to fixed CO_2-systems should be locked in the fully open position using nonbreakable shackle locks, and chains if necessary. Physical testing of control valves as in Recommendation No. 1, may be done on a monthly basis after locks are installed.

3. Upgrade the existing ERT's.

   Fires and other accidents will happen despite the best efforts to prevent them. Property planned action at the start of an emergency can mean the difference between a minor incident and a major catastrophe. Hence, to handle fire emergencies, the existing ERT's should be upgraded by the following assignments of specific individuals and their alternates on each operational shift for tht designated duties:

   a) a person to take direct charge of the emergency;

   b) a person to call the fire department and to direct fire department personnel to the scene of the fire upon their arrival;

c) a person to each fire protection control valve, who in the event of a fire alarm, goes to the valve controlling water supplies/carbon dioxide to the automatic protection system in the fire area, makes sure it is fully open, keeps it fully open until asked by the fire chief to shut it and remains at the valve to reopen it if needed and until automatic protection is restored. If indoor control valves are located in the fire area, this recommendation should be executed with judgment, taking life safety of the person into consideration;

d) An adequate number of persons trained in the use of fire extinguishers and in the after-fire salvage operation.

Periodic training sessions to reinstruct the members in their duties and to update the organization should be scheduled.

9.2 POLICY RECOMMENDATIONS

1. Establish a uniform policy concerning the installation of fire detectors in structures of equivalent mission priority.
2. Establish a uniform policy for the installation of automatic sprinkler systems in at least those occupancies indicated in Table IV.
3. When changes in occupancy occur, such as the photographic, document reproduction and storage areas in Building 5, fire resistive construction and automatic detection and suppression should be considered at the planning stage.

X
ESTIMATED COST FOR RECOMMENDATIONS

10.1 AUTOMATIC SPRINKLER PROTECTION

At the present time it is estimated that automatic sprinkler systems can be installed at approximately $100.00 per head/100 sq ft of floor area to be protected. This figure includes connections to a water supply line, division values, risers etc.

10.2 SMOKE DETECTORS

The Center apparently has found ionization smoke detectors most suited for the detection of incipient fires. Currently, two methods of installing such devices are used by the Center, namely, contractor installation or direct purchase of the devices with engineering consultation provided by the device manufacturer, with the actual installation performed by Center personnel.

Assuming the first method of having a contractor provide and install the ionization type of smoke detector, an estimated cost of $106/head has been provided by a contractor.

Data for the second method, based upon 1972 figures, indicate the cost of associated hardware* to be in the range of $0.50 to $1.00/sq ft plus an additional 45 percent of the total hardware costs plus the cost of the detector.

From these cost estimates one can determine an approximate price for implementing all or parts of the recommendations for fire protection and detection systems.

* exclusive of the detector